JC03 Rec'd PCT/PTO 09 MAR 2001

FORM PTO-1390 (REV. 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER **2345/146**
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/786826

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED:
PCT/EP99/05664	**05 August 1999 (05.08.99)**	**09 September 1998 (09.09.98)**

TITLE OF INVENTION
OPTICAL COMMUNICATIONS LINK

APPLICANT(S) FOR DO/EO/US
Wolfgang DULTZ, Gisela DULTZ, Erna FRINS and Heidrun SCHMITZER

Applicant(s) herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (UNSIGNED)
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report (translated), Preliminary Examination Report (translated), and Form PCT/RO/101.

Express Mail No.: EL302703416

JC02 Rec'd PCT/PTO 0 9 MAR 2001

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/786826	PCT/EP99/05664	2345/146

17. ☒ The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5)):

Search Report has been prepared by the EPO or JPO $860.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $690.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) $710.00

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO $1,000.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 860.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	14 - 20 =	0	X $18.00	$	
Independent Claims	2 - 3 =	0	X $80.00	$	
Multiple dependent claim(s) (if applicable)			+ $270.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 860.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$860.00	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 860.00	
TOTAL FEES ENCLOSED =				$ 860.00	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of $ 860.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

By: [signature] Reg No 35952

SEND ALL CORRESPONDENCE TO:

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3/9/01
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PATENT TRADEMARK OFFICE

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[2345/146]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Wolfgang DULTZ et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	OPTICAL COMMUNICATIONS LINK
Examiner	:	To Be Assigned
Art Unit	:	To Be Assigned

09786826.030401

Assistant Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

SIR:

Kindly amend the above-identified application before examination, as set forth below.

IN THE TITLE:

Please replace the title with the following:
--OPTICAL COMMUNICATIONS LINK--.

IN THE SPECIFICATION:

Please amend the specification, including abstract, pursuant to the attached substitute specification. Also attached is a red-lined copy of the specification, indicating deleted and added sections. No new matter has been added.

EL302703402

IN THE CLAIMS:

Please cancel original claims 1-14 without prejudice.

Please add the following new claims:

15. (New) An optical communications link comprising:

an optical fiber for transmitting information, the optical fiber having a plurality of fiber sections, each fiber section of the plurality of fiber sections being configured to have at least one of a right-hand curvature and a left-hand curvature, the optical fiber being bent repeatedly so that the plurality of fiber sections having a right-hand curvature and a left-hand curvature are distributed over the optical communications link so that an average torsion of the optical fiber over the optical communications link is about zero.

16. (New) The optical communications link as recited in claim 15, wherein the optical fiber is bent so that a torsion of the fiber section of the plurality of fiber sections averaged over a total subsections of the communications link is about zero.

17. (New) The optical communications link as recited in claim 15, wherein the optical fiber is wound in a helical shape, alternating with a right-hand and left-hand winding helix.

18. (New) The optical communications link as recited in claim 17, wherein the right-hand and left-hand winding helix includes a right-hand helical winding and a left-hand helical winding so that the right-hand helical winding follows and alternates with the left-hand helical winding, a right length of the right-hand helical winding corresponding to a left length of the left-hand helical winding.

19. (New) The optical communications link as recited in claim 15, further comprising an elastic carrier material, the elastic carrier material being joined to the optical fiber so that a form change of a transmission line is permitted and so that in

response to no mechanical load the transmission line retains the optical fiber in its initial curved form, the transmission line configured as a plurality of the optical fibers.

20. (New) The optical communications link as recited in claim 15, further comprising a carrier element, the carrier element being an at least one of an elongated carrier element and a cylinder, the optical fiber being wound around the carrier element.

21. (New) The optical communications link as recited in claim 20, the at least one of the elongated carrier element and the cylinder is flexible.

22. (New) The optical communications link as recited in claim 20, wherein the optical fiber is secured to the carrier element so that the optical fiber is movable and still stabilized on the carrier element.

23. (New) The optical communications link as recited in claim 22, further comprising a cladding material, the optical fiber being at least one of flush mounted on the carrier element and embedded between the carrier element and the cladding material.

24. (New) The optical communications link as recited in claim 20, wherein the optical fiber is coiled with an alternating winding direction around one of two carrier elements disposed side-by-side and an even number of the carrier elements disposed side-by-side.

25. (New) The optical communications link as recited in claim 20, wherein a left-number of the left-hand windings around a first of the carrier elements is equivalent to a right-number of the right -hand windings around a second of the carrier elements.

26. (New) An optical communications link comprising:

a first optical fiber for transmitting information, the first optical fiber having a first plurality of fiber sections, each fiber section of the plurality of fiber sections being configured to have at least one of a first right-hand curvature and a second left-hand curvature, the first optical fiber being bent repeatedly so that the first plurality of fiber sections having a first right-hand curvature and a first left-hand curvature is distributed over the optical communications link so that a first average torsion of the first optical fiber over the optical communications link is about zero;

a second optical fiber for transmitting information, the second optical fiber having a second plurality of fiber sections, each fiber section of the second plurality of fiber sections being configured to have at least one of a second right-hand curvature and a second left-hand curvature, the second optical fiber being bent repeatedly so that the second plurality of fiber sections having a second right-hand curvature and a second left-hand curvature are distributed over the optical communications link so that a second average torsion of the second optical fiber over the optical communications link is about zero;

the first and the second optical fibers being helically wound and having different winding directions so that the first optical fiber directs light in a forward direction and the second optical fiber directs light in a return direction.

27. (New) The optical communications link as recited in claim 26, wherein the first optical fiber and the second optical fiber are wound around the same carrier element producing an outer winding of a larger coil pitch than an inner winding so that a first torsion of a forward line of the first optical fiber is similar in magnitude to a second torsion of a return line of the second optical fiber, the first torsion and the second torsion having different operational signs.

28. (New) The optical communications link as recited in claim 26, wherein the optical fiber has a winding radius of one of greater than 2 cm and greater than 3 cm.

REMARKS

This Preliminary Amendment cancels, without prejudice, original claims 1-14 in the underlying PCT Application No. PCT/EP99/05664, and adds new claims 15-28. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

The amendments to the specification and abstract reflected in the substitute specification are to conform the specification and abstract to U.S. Patent and Trademark Office rules, and do not introduce new matter into the application.

The underlying PCT Application No. PCT/EP99/05664 includes an International Search Report, issued February 4, 2000, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

The underlying PCT Application No. PCT/EP99/05664 also includes an International Preliminary Examination Report, issued December 13, 2000, a copy of which is included, including a translation.

Applicants assert that the present invention is new, non-obvious, and useful. Prompt consideration and allowance of the claims are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

By [signature] Reg No 35,952

Dated: 3/9/01

By: [signature]
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[2345/146]

OPTICAL COMMUNICATIONS LINK

Technical Field

The present invention is directed to a movable optical communications link having at least one optical fiber, in particular for use in transmitting information or performing interferometric measurements.

Background of the Invention

Optical fiber links used to transmit information via light have significant advantages, both for long transmission links in telecommunications, as well as for short transmission links inside buildings, vehicles, and machines, not to mention in electronic calculating machines, since they ensure high data transmission density accompanied by low power losses. Due to their thin, flexible, but mechanically very durable construction, incoming optical fiber lines and outgoing optical fiber lines are beneficial, particularly for connecting optical sensors for measuring physical parameters, such as pressure and temperature, etc. In addition, unlike electrical connections, they cannot cause any electrical sparkovers or short circuits. The high transmission capacity of the optical fibers makes it possible to modify or replace the sensors and measuring devices without having to replace the communication links. This can result in considerable cost savings in vehicles, buildings, machines, or production facilities. There is often the need for optical fiber links to be mechanically movable, such as when installed in robots. In buildings and vehicles, as well, one frequently

encounters motion among components due to strain or expansion.

Therefore, optical fiber links for transmitting information are always of great benefit when there is a need to transmit high information densities and a mechanically flexible connection is required, since the distance between the sender and receiver of the information varies as a function of time.

Here, the problem arises that significant changes in the position of the transmitter and/or of the receiver, and, in particular, in their relative distance spanned by optical communication links constituted as simple cable, can cause the entire system, such as a remote-controlled robot, to be obstructed by the requisite reserved length of cable. It can happen that individual components, which communicate with one another via an optical communications link, become mechanically blocked by loops of cable. Another problem is that one can end up with a "cable salad".

Another problem encountered in response to variations in the position and distance of transmitters and/or receivers has to do with the nature of the optical transmission signal:

In communications transmissions of high quality and transmission frequency, it is necessary to control the polarization state of the optical information flow in the optical fiber, as well as in the other optical components. In the case of coherent transmissions, for example, phase-coherent mixing of the optical information flow with other light sources must be carried out. This is only optimal when the polarization states are

substantially identical. When working with high bit-rate transmissions, the polarization mode dispersion of the fibers limits the reception quality, and transmission frequency can only be increased by carefully controlling the polarization. In many other optical components as well, the performance is a function of the polarization of the light.

Generally, the polarization state of the light in an optical fiber is not constant. Each glass fiber has a certain elliptical birefringence, so that the polarization of the light continually changes in the fiber. This variation propagates through to the end of the fiber, and, since it is dependent upon the spatial geometry of the fiber curve, the polarization state at the output end of a moving fiber varies with the motion.

In known methods heretofore, this polarization effect is avoided in that the optical communications transmission takes place in one of the intrinsic modes of a polarization-maintaining fiber. These polarization-maintaining fibers are characterized by pronounced birefringence, so that there is virtually no coupling over between the two polarization modes in the fiber. Since a change in the polarization of the light in an optical fiber is a phase shift effect between the intrinsic modes of the light, the polarization mode dispersion does not occur when the light in the fiber propagates through permanently in one intrinsic mode only.

The drawback of this method is that the polarization-maintaining fibers are expensive. Moreover, the light must be launched at the input ends of the polarization-maintaining fiber in a defined polarization

state.

Technical Object

The object of the present invention is, therefore, to provide an optical communications link which will overcome the described problems. In particular, to ensure a high transmission quality, the polarization state of the light should not depend substantially on changes in the form of the communications link and, therefore, on changes in the position of the transmitters and receivers. In addition, the communications link should be easily adaptable to changes in form, in particular to variations in length, but, it in this context, always be characterized by a straightforward arrangement.

Detailed Description of the Invention

The objective is achieved by an optical communications link having at least one optical fiber, in particular for communications transmission, where the optical fiber is repeatedly bent and, in the process, is wound in a helical shape, alternating as a right-hand and left-hand helix, fiber sections having a right and left curvature being distributed in such a way over the communications link that the average torsion of the fiber over the communications link is approximately zero.

Thus, the optical communications link of the present invention is designed in such a way that the sensitivity of the polarization state of the optical transmission signal to changes in the form of the communications link and, i.e., of the optical fibers is substantially compensated. This is assured by the present invention in that the optical fiber is repeatedly bent, fiber sections

having left-hand and right-hand curvature being distributed in such a way over the communications link that the average torsion of the fiber over the communications link is more or less zero. Preferably, this also holds for individual subsections of the fiber, so that left and right curvatures are uniformly distributed over the fiber. By preference, the fiber is wound in a helical shape, alternating with a right-hand and left-hand helix. Mixed forms having an even meander shape are also possible.

The basis of this invention is the motion-and form-dependent birefringence of an optical fiber: the linear birefringence is heavily dependent upon the ellipticity are the fiber core, less heavily dependent upon the bend of the fiber, and hardly dependent upon the helical winding, given a large radius of the fiber. In contrast, the circular birefringence is hardly dependent upon the ellipticity of the fiber core and on the curve of the fiber, on the other hand, very heavily dependent upon the helical winding of the fiber. The main reason for the form dependency of the polarization state at the output end of an optical fiber is the considerable dependency of the fiber's optical activity upon the exact form of its helical windings. In the first approximation, this effect is achromatic and does not result in any polarization mode dispersion. It is caused by one of the so-called optical Berry phases, the "spin redirection phase" (R.Y. Chiao, Y.S. Wu, Phys. Rev. Lett. 57, 933 (1986)). This Berry phase (or geometric phase) is a phase effect produced by the structure of the fiber's space curve and not by an optical path, as is the case with the normal dynamic phase of the light. Nevertheless, with respect to interference of the light, geometric phases have the same properties as the normal dynamic phase.

The size of the spin redirection phase in a helically wound fiber is equivalent to the solid angle Ω that the k vector (k corresponds to the propagation constant β in the technical literature) wraps around on the sphere of the light-propagation orientations in the counter clockwise-direction when the light in the fiber is directed through a helical winding. The spin redirection phase is additive and changes its operational sign when the helical direction of the fiber changes, e.g., from the left-hand to the right-hand helix.

To minimize this form-dependent polarization effect, the fiber must be made up of wound fiber sections having alternating winding directions. As an example, the fiber sections are alternately wound to the right and to the left, the space angle, which wraps around the k vector in the left-hand wound sections, being equivalent to the space angle that the k vector wraps around in the right-hand wound sections. In the simplest case, the fiber alternately follows a right-hand and then a left-hand helix, each time with an equivalent length and winding; or right-hand and left-hand wound fiber sections of a fixed length alternate with each other.

To reduce the polarization dependency of changes in the form of the fiber link, the sections having right-hand and left-hand helical winding of the fiber must be distributed over the fiber in such a way that, in response to an altered fiber form, the changes $d\Omega_i$ in the solid angles Ω_i of the k vectors in the i-th fiber section add up to zero, thus to
$\Sigma\ d\Omega_i = 0$.

The variation in the polarization of an optical signal at the output end of a moving optical communications link

having one optical fiber is advantageously reduced in that the optical fiber is repeatedly bent, fiber sections having a right and left curvature being distributed in such a way over the communications link that the average torsion of the fiber over the communications link is approximately zero.

In order to minimize the variation in polarization in the case of changes in the form of only one fiber section, the optical fiber is preferably bent in such a way that the torsion of the subsection averaged over subsections of the communications link is approximately zero. In this context, a subsection is a fiber section which is at least sufficiently long to contain right-hand and left-hand fiber segments, e.g., two successive, individual right-hand and left-hand windings, the torsion of the two sections canceling each other.

The optical fiber is advantageously coiled with alternating winding direction around an even number of, preferably two, side-by-side carrier elements. In this context, one or a plurality of left-hand windings around one of the carrier elements can follow the corresponding number of right-hand windings around another carrier element.

Another embodiment of the communications link provides for two helically wound optical fibers (1, 3, 6) having different winding directions in order to direct the light in the forward and return directions.

In this further embodiment, the communications link has at least two helically wound optical fibers having different winding directions to direct the light in the forward and return directions. In this context, both

optical fibers can be advantageously wound around the same carrier element, the outer winding of the two windings having a somewhat larger coil pitch, so that, in terms of absolute value, the torsion of the forward and return line is more or less equivalent, but with different operational signs.

Thus, the communications link in accordance with the present invention permits the transmission of information in moving fibers, with a substantially reduced polarization variation at the output end.

To minimize the effects of the bending- and stress-induced birefringence of the fiber material on the polarization state of the transmission signal, one should not select too small of a winding radius for the optical fibers. Preferably, it should amount to at least 2 cm, in particular to at least 3 cm.

In a further advantageous embodiment of the present invention, the optical fiber is joined to an elastic carrier material, which, in response to mechanical loading, permits a change in the form of the transmission line and, in response to the lack of a mechanical load, retains the optical fiber in its initial curved form.

This communications link makes it possible to establish a connection that is compact, yet movable and variable in length, for transferring optical data between a transmitter and a receiver. In this manner, one minimizes any mechanical hindrance to the overall device, including the transmitter, receiver and communications link. Furthermore, the output signal is substantially insensitive to any changes in the form of the communications link.

By preference, the optical fiber is wound in a helical shape, e.g., in the manner of a telephone cable. In response to stress in the longitudinal direction of the helix, i.e., of the meander shape, the communications link can be pulled apart in an accordion-like fashion, and, in response to cancellation of the stress, again assumes its compact, initial form.

In another advantageous further refinement, the optical fiber is wound around at least one elongated carrier element, such as a cylinder. The carrier element is preferably flexible. As an example, the carrier element is a flexible bar.

To realize and stabilize its curved form, the fiber is preferably secured to the carrier element in such a way that it is movable in its wound form, but remains stabilized on the carrier element, e.g., in that it is flush mounted on the carrier element or embedded between the carrier element and a cladding material.

The following is a brief description of the drawing, whose figures show:

Figures 1 through 3	examples of the transmission lines according to the present invention for reducing the influence of form on the polarization of the output signal.

Figures 1 through 3 illustrate examples of transmission lines according to the present invention which are compact, movable, and flexible. Furthermore, they are designed to minimize the influence of the transmission

line's form on the polarization of the output signal. Thus, they are especially suited for linking optical transmitters and receivers, which are movable with respect to one another, for purposes of data communications.

The top part of Figure 1 shows a detail of such a communications link, which is made up of a cylinder 2, as a carrier material or carrier element, and of an optical fiber 1. Optical fiber 1 is helically wound around cylinder 2, the direction of the helical winding changing, for instance, in the middle of the cylinder at point B. Thus, in the left part of the communications link, the torsion of the optical fiber is negative, in the right part, positive, so that the average torsion is more or less zero.

To change the direction of the helical winding on a cylinder, an arc B must be wound. This arc is secured, together with the remaining right- and left-hand winding, for example, by adhesive or by tying it to the cylinder, since otherwise it would become detached.

To manufacture a long communications link, a plurality of line segments can be joined to one another, as shown in Figure 1. The depicted fiber segment is then a subsection, in which the average torsion is approximately zero.

In the lower part of Figure 1, the k vector of the light launched into the fiber and the corresponding solid angle Ω are shown. If r(s) denotes the space curve described by the fiber as a function of the arc length s, then solid angle Ω is derived as a measure for the Berry phase from the torsion τ of the space curve, as follows (s_1, s_2

denote the beginning and end, respectively, of the fiber):

$$\int_{s1}^{s2} \tau(s)ds = \Omega \propto \Phi_{Berry}, \text{ where } k(s1) = k(s2)$$

Two further examples of communications links or of sections thereof, in accordance with the present invention, are shown in Figure 2. In Figure 2A, optical fiber 3 is doubly wound over two cylinders 4, 5. Around cylinder 4, fiber 3 describes a left-hand winding (L), around cylinder 5, a right-hand winding (R). By alternating the two cylinders, a right-hand helical winding and a left-hand helical winding always alternate with one another.

In this context, glass fiber 3 is embedded, similarly to a telephone line, in a material which has dimensional stability, but is highly elastic, so that the incoming line can be pulled apart in accordion-like fashion, but contracts again when the tensional force subsides. In addition, cylinders 4, 5 can themselves be resilient to facilitate a lateral motion of the communications link.

The optical signal can be conducted in the reverse direction through the same glass fiber, however, over a different spectral channel, for example. Since the geometric phase is achromatic, and a right-hand helix (left-hand helix) remains a right-hand helix (left-hand helix) when it is propagated through in the opposite direction, the same compensation effect occurs for the optical forward and reverse line as does for the form-dependent polarization fluctuations.

In place of two cylinder windings as shown in Figure 2A, the fiber can also be routed over more cylinders, i.e., four cylinders 7, 8, 9, 10. This is shown in Figure 2B. In the case of 2B, right-hand and left-hand loops alternate, each characterized by R or L.

It is also fundamentally possible for a plurality of left-hand loops to follow a plurality of right-hand loops in that the fiber is repeatedly wound around a cylinder before it is routed to the next cylinder with an opposite winding direction. It is crucial here that the formula $\Sigma\, d\Omega_i=0$ remain satisfied, and that the torsion of the entire optical fiber be compensated.

The achromaticity of the geometric phase makes it possible to use both white light sources, as well as more or less monochromatic light sources.

In the case that the light is directed in the forward and reverse direction through the same communications link, it is possible to configure two cylinder windings side-by-side, one of these, a right-hand helix, functioning as an incoming line, and the other, a left-hand helix, as a return line. The flexible claddings, which determine the form elasticity of the line, can be configured separately from one another. However, they are advantageously designed as contiguous claddings. This prevents them from separating from another, thereby permitting them to jointly participate in the motion of the line, substantially identically.

Claims

1. An optical communications link having at least one optical fiber, in particular for transmitting information, characterized in that the optical fiber is bent repeatedly, fiber sections having right-hand and left-hand curvature being distributed in such a way over the communications link that the average torsion of the fiber over the communications link is approximately zero.

2. The optical communications link as recited in Claim 1, characterized in that the optical fiber is bent in such a way that the torsion of the subsection averaged over subsections of the communications link is approximately zero.

3. The optical communications link as recited in Claim 1 or 2, characterized in that the optical fiber is wound in a helical shape, alternating with a right-hand and left-hand helix.

4. The optical communications link as recited in Claim 3, characterized in that one or a plurality of right-hand windings follow one or a plurality of left-hand windings and alternate with one another, the length of the fiber segment having the right-hand helical winding corresponding to the length of the fiber segment having the left-hand helical winding.

5. The optical communications link as recited in one of Claims 1 through 4, characterized in that the optical fiber is joined to an elastic carrier material, which, in response to mechanical loading, permits a change in the form of the transmission line and, in response to the lack of a mechanical load, retains the optical fiber in

its initial curved form.

6. The optical communications link as recited in one of Claims 1 through 5, characterized in that the optical fiber is wound around at least one elongated carrier element, preferably a cylinder.

7. The optical communications link as recited in Claim 6, characterized in that the carrier element is flexible.

8. The optical communications link as recited in one of the Claims 6 or 7, characterized in that the fiber is secured to the carrier element in such a way that it is movable in its wound form, but remains stabilized on the carrier element.

9. The optical communications link as recited in Claim 8, characterized in that the fiber is flush mounted on the carrier element or embedded between the carrier element and a cladding material.

10. The optical communications link as recited in one of Claims 6 through 9, characterized in that the optical fiber is coiled with alternating winding direction around an even number of, preferably two, side-by-side carrier elements.

11. The optical communications link as recited in one of Claims 6 through 10, characterized in that one or a plurality of left-hand windings around one of the carrier elements is equivalent to the number of right-hand windings around another carrier element.

12. The optical communications link as recited in one of the preceding claims, characterized in that it has at

least two helically wound optical fibers having different winding directions to direct the light in the forward and return directions.

13. The optical communications link as recited in Claim 12, characterized in that both optical fibers are wound around the same carrier element, the outer winding of the two windings having a somewhat larger coil pitch, so that the torsion of the forward and return lines is more or less equivalent, but has different operational signs.

14. The optical communications link as recited in one of the preceding claims, characterized in that the winding radius of the optical fibers is greater than 2 cm, preferably greater than 3 cm.

Abstract

The present invention is directed to an optical communications link having at least one optical fiber, in particular for communications transmission, where the optical fiber is repeatedly bent, fiber sections having a right-hand and left-hand curvature being distributed in such a way over the communications link that the average torsion of the fiber is approximately zero. The communications link in accordance with the present invention is compact, flexible, and, in particular, variable in length. In addition, it reduces the sensitivity of the polarization state of the optical signal to changes in the form of the communications link.

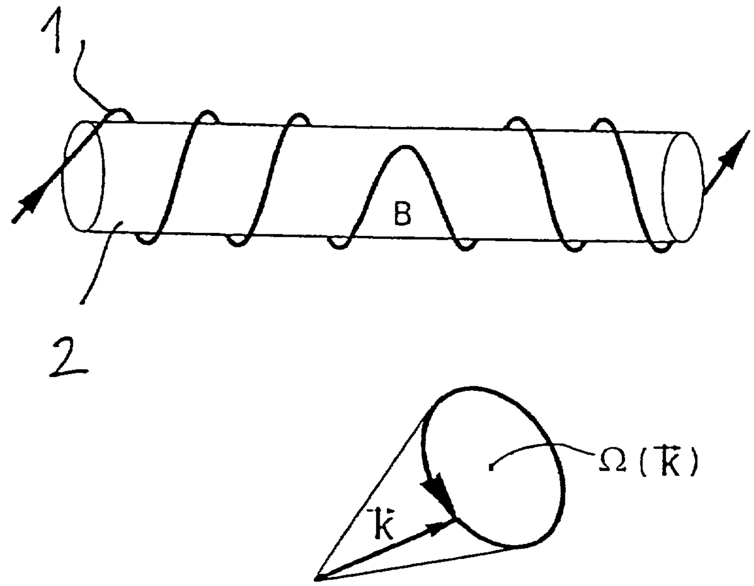
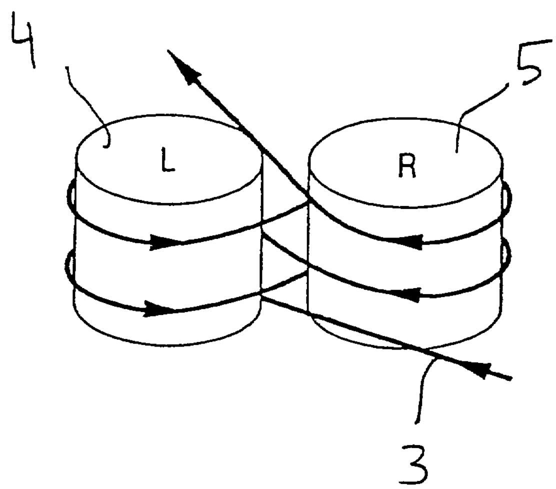


FIG. 1



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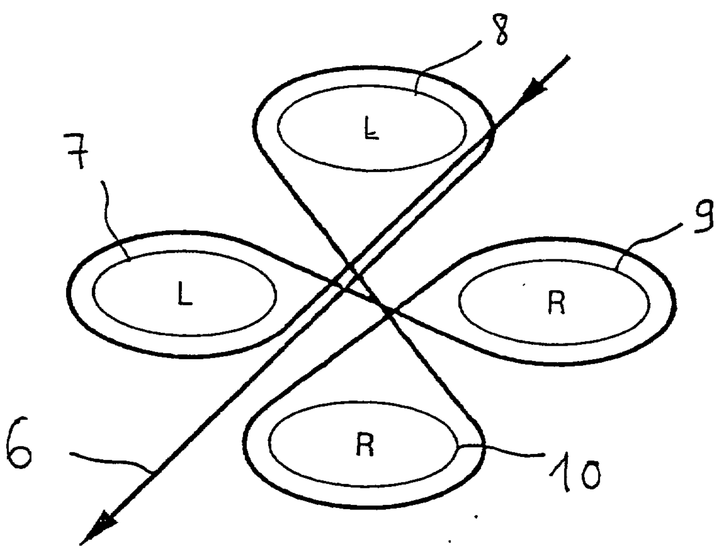

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FIG. 2

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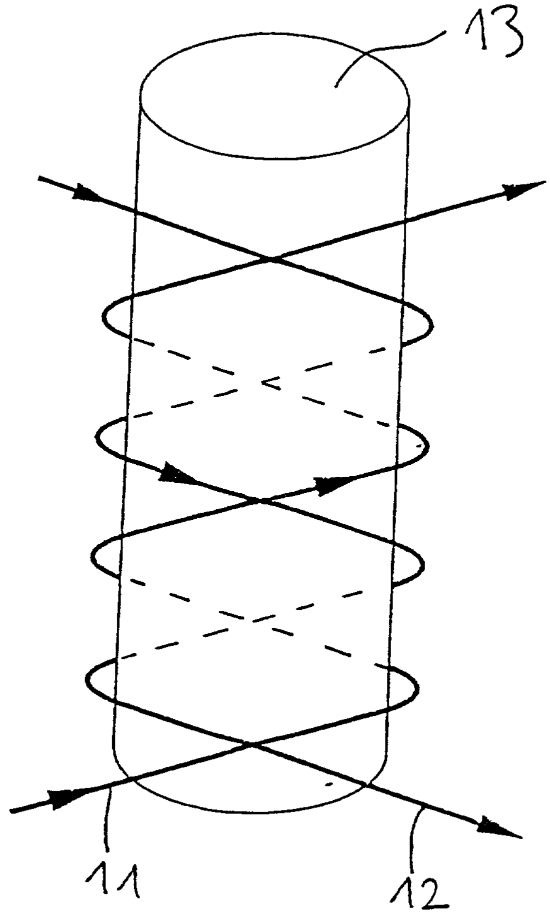

FIG. 3

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[2345/146]

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **OPTICAL COMMUNICATIONS LINK**, the specification of which was filed as International Application No. PCT/EP99/05664 on August 5, 1999 and filed as a U.S. application having Serial No. 09/786,826 on March 9, 2001, for Letters Patent in the U.S.P.T.O.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number	Country Filed	Day/Month/Year	Priority Claimed Under 35 USC 119
198 41 068.9	Fed. Rep. of Germany	9 September, 1998	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490), Gerard A. Messina (Reg. No. 35,952) and Linda M. Shudy (Reg. No. 47,084) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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